Report of the 17th Electron Ion Collider Detector R&D Meeting

EIC Detector Advisory Committee

July 11 – 12, 2019

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Introduction

BNL, in association with Jefferson Laboratory and the DOE Office of Nuclear Physics, has established a generic detector R&D program to address the scientific requirements for measurements at a future Electron Ion Collider (EIC). The primary goals of this program are to develop detector technologies and detector concepts that are suited to experiments in an EIC environment, which will ensure that the full physics potential of an EIC can be harvested and that the resources for implementing these technologies are well established within the EIC user community.

The EIC Detector Advisory Committee meets twice a year, typically in January and in July. The current Committee members are: M. Demarteau (ORNL/Chair), C. Haber (LBNL), P. Križan (Ljubljana University/J. Stefan Institute), B. Ratcliff (SLAC), I. Shipsey (Oxford University), R. Van Berg (U. Pennsylvania), J. Va'vra (SLAC) and G. Young (BNL). Not able to attend this meeting were Peter Križan, Blair Ratcliff and Ian Shipsey due to conflicting obligations. During the January meeting progress reports are reviewed and feedback is provided to the proponents. During the July meeting both progress reports and new proposals are reviewed. Funding recommendations for continuation of existing and for new proposals are provided by the Advisory Committee to the program manager in advance of the fiscal year funding cycle.

Prior to the meeting, three new proposals were submitted to the committee by the May 24, 2019 deadline. Feedback on the new proposals was submitted to the proponents on June 11, 2019 with guidance on how to strengthen the proposals. All new proposals were endorsed to proceed to submitting a full proposal. The committee received progress reports and funding requests of all continuing projects and the new proposals on June 21, 2019.

At this meeting status reports were provided by ten funded projects. No report nor presentation was made by eRD15. The Committee met at Brookhaven National Laboratory on July 11 and 12, 2019 to hear the status reports and discuss the progress with the proponents. The committee would like to thank all collaborations for their excellent presentations and status reports and BNL for its hospitality. The collaborations are to be commended for their progress. It is gratifying to see results being published in peer-reviewed journals, and all proponents are strongly encouraged to continue to publish their results. The funding recommendation is presented in Table 1 at the end of this report.

General Remarks

With the release of the report of the National Academy of Sciences (NAS) on July 24, 2018 giving their strong support for the construction of an electron–ion collider (EIC), the planning for the project has gained momentum. Both Brookhaven and Jefferson Laboratory have submitted a detailed cost estimate for their respective designs, which have been reviewed in May 2019. The report of the review committee is expected to be submitted in August. It is expected that this fiscal or calendar year the project will receive the Mission Need endorsement (CD-0) from the Office of Science followed soon thereafter by the site selection. A notional timeline for the detectors shows that Technical Design Reports are expected to be submitted in 2023, with a seven-year construction schedule. This gives a submission of a Conceptual Design Report in 2021, which leaves very little time to bring detector research to a technological readiness level to be included in a defensible way in the Conceptual Design Reports. The committee feels that in several areas the community is still far away from being able to produce a defensible CDR. The original

goal of this program, established in 2011, was to encourage generic detector R&D for the EIC. Given that the creation of an EIC project is imminent the mandate of this committee has changed, and the committee's guidance will shift towards more directed R&D to enable readiness for submission of a CDR on the anticipated timescale. The next sections provide the committee's assessment on the progress of the eRD collaborations with the new focus of preparation for defensible design reports. All consortia are to be commended on the excellent work that is being carried out enabling the EIC science.

We note again that with the EIC now moving towards project status with CD-0 imminent, this is a perfect time for proposals to be submitted to the DOE sponsored Early Career Award Program (https://science.energy.gov/early-career/). We strongly encourage junior U.S. faculty to take advantage of this program. Given the high priority of the EIC within the Office of Nuclear Physics, proposals with an instrumentation element that enables a key goal of the EIC physics program should be very well received. We also note the NSF Faculty Early Career Development (CAREER) Program that is available to the university community (https://www.nsf.gov/career).

eRD1: EIC Calorimetry

O. Tsai, T. Horn and C. Woody reporting

Tungsten-fiber calorimeter development

sPHENIX is now deploying a W-powder SciFi matrix for use as an EM-Calorimeter with some 500 prototype towers already built and a pre-production run of over 4000 towers well-underway. The general development of W/SciFi EM-Calorimeters has now led to working prototypes with good energy and position resolutions, a choice of SiPMs for readout technology, all coupled with levels of radiation hardness that would result in a capable EM calorimeter for the barrel and hadron-going directions at an EIC, and indeed appears ready to be incorporated into the design of an EIC detector. The sPHENIX device now includes choices for the front-end electronics, light guides and reflectors, monitoring devices and cooling technology. Indeed the sPHENIX design has nearly attained PD-2/3 approval, indicating that system and cost/schedule matters are also successfully addressed, a matter of considerable interest in attaining a future EIC CD-2/3.

There is still room for improving readout performance, as noted by the eRD1 group. Prior reports by the eRD1 group of results from FNAL test beam runs indicate that response uniformity across the matrix could be improved by better photo-sensor coverage. A solution that also avoided the depth lost to light guides is of interest in an EIC detector barrel region, which needs to be inside the magnet coil. The team presented a concept for tiling of the readout face of an sPHENIX block (2x2 towers) using newly available 6x6mm^2 SiPMs from HPK. These SiPMs also exhibit improved noise performance compared to the (now-discontinued!) series just being procured for sPHENIX. An EIC detector needs an improved uniformity over that accepted for sPHENIX, and deployment of a fully 'tiled' SiPM readout presents a possible path to achieve this.

The collaboration presented further analysis of their continued measurement of the effects of radiation exposure to the long-term performance of SiPMs. The Committee encourages continuation of this and would be interested to know the radiation tolerance of the newer, larger 6x6mm^2 SiPMs. This study also points to the need for a good monitoring system for a W-SciFi calorimeter, more so given the SiPM aging behavior. Whether cooling is needed will need to be studied. The results of these studies are of interest for readout of other EIC detectors, such as Cerenkov detectors.

The Committee congratulates the group on the completion of this particular line of R&D. It is looking forward to possible future new proposals addressing issues noted above, notably concerning light-collection uniformity.

HCAL Studies, in particular Timing

The collaboration has studied the time-development out to 1000 ns of the light signals from Fe/Sc/WLS calorimeters using an existing device. They have performed in parallel simulation studies of the performance, examined the light yield from neutrons, determined that Pb is preferable to Fe to obtain more neutrons from the shower, and studied the timing of existing, albeit somewhat slow, scintillator and WLS fibers and compared the results to the signal timing expected for faster fluors. The results for Fe-based devices are not particularly encouraging for event-by-event improvement of hadronic shower response but those for a Pb (or W) based system might very well be. The Committee is interested to see further opportunistic pursuit of this concept using available metal plates perhaps coupled with newly-

obtained faster scintillators and wavelength shifters. If a W or Pb/SciFi device were available of some 5-6 interaction lengths longitudinal scale, that would be of significant interest to test.

Shashlik Concept

The Committee takes note of the continued development of the shashlik development at UTFSM using W-Cu plates to realize a compact shashlik EMCal. Six towers are constructed, with more planned, and readied for readout studies. Coupling to available electronics from sPHENIX is pursued with an eye to measure performance in a test beam. A simulation effort is underway to understand light production and collection from the shashlik tiles with an eye to studying e.g. various reflectors and surface treatments. A 'short stack' was constructed to permit light collection studies and is in process of being connected to borrowed sPHENIX electronics to reach required noise levels. The comparisons, suggested at the last meeting, to the performance of the old PHENIX shashlik EMCal towers, reconfigured to read out the individual WLS fibers, are still pending, awaiting finding manpower for this effort.

The Committee commends the progress shown and looks forward to further reports.

Recommendation
The Committee congratulates the consortium on finishing the Tungsten-fiber calorimeter effort. The timing studies for the hadron forward calorimeter is encouraged, but the shashlik calorimeter effort should receive higher priority to allow a quantitative comparison with other technologies by the time of a CDR.

Crystal calorimeter development

The Committee takes note of the ongoing effort to characterize lead-tungstate crystals from Crytur and SICCAS and recognizes the need to qualify a vendor in order to be able to propose a high-resolution scintillating crystal EMCal for the EIC. Continued progress is made in acquiring crystals from SICCAS and from CRYTUR. There remain concerns about materials control and purity, as well as crystal handling, at SICCAS. The issue with CRYTUR seems more to be one of factory capacity, which could well be resolved should a large order be needed. The distribution in light yield from the recent set of crystals from CRYTUR is has a sigma/mean of only 5% which is very good. That for SICCAS remains at 15%, which is worrying for crystal-to-crystal uniformity in what must be a high-resolution forward EM-Calorimeter. The sources of new raw material for CRYTUR and control of its purity appear to be issues going forward. The uniformity results presented for CRYTUR crystals are particularly encouraging, with no rejection of recently-acquired crystals.

The effort for the EIC benefits from the work being done for the Neutral Photon Spectrometer at JLab by several of the same people.

The collaboration has now tested both a 12x12 array and a 3x3 array of $PbWO_4$ crystals in JLab Hall D, where tagged photons of 1-10 GeV are available. Energy resolution over a range of photon energies from 3 to 10 GeV was measured, resulting in a 2.2% stochastic term and a 0.7% constant term, which is encouraging for the forward deployment at EIC. The Committee looks forward to further systematic results on energy and position resolution and takes note of the collaboration's pro-active efforts here.

The Committee also takes note of the planned radiation studies using hadron beams from a MC40 cyclotron.

The Committee is pleased with this energetic effort and looks forward to the future reports of the collaboration and their planned path forward.

Scintillating Glasses

The collaboration reported further results on radiation hardness (up to 6000 Gy (600 kRad TID) of 160 keV x-rays), transmission vs. wavelength, and fluorescent light yield for160 nm excitation, for samples of scintillating glasses. Some glasses perform well under large radiation dose, whilst other formulations were disqualified by these tests. Large fluorescence light yields relative to $PbWO_4$ were noted. Methods to control bubbles and localize them to the surface were shown. Tuning of glass composition to control radiation hardness and peak wavelength of light yield was demonstrated. Densities above that of lead glass can be achieved, which makes these glasses of interest in the central region at EIC. Samples of 2x2x4 cm^3 scale were exhibited to the Committee of two scintillating glass types, with excellent surface quality, good transparency and absence of bubbles. This is very encouraging. Near-term plans include measurement of light yield from cosmic-ray events, which is of great interest to the Committee.

The density, Molière radius and radiation lengths achieved were discussed together with what could be done to adjust them. There is a strong interest in a short radiation-length glass that would permit deployment of physically short towers, yet of 18-20 radiation-lengths extent, in the central region at the EIC, where the EM-Calorimeter must be radially inside the magnet coil.

Recommendation
The Committee recommends continuing leveraging the crystal development with the effort for the Neutral Photon Spectrometer at JLab and be supported through that effort. The effort on the glass research is strongly encouraged and it is recommended that all funding be directed towards the glass development to accelerate this R&D.

eRD6: Tracking Consortium for the EIC

M. Posik reporting

The eRD6 collaboration reported on a broad range of efforts on Micro-Pattern Gas Detectors (MPGDs) for tracking and particle identification, which covered the TPC and cylindrical μRWELL efforts for central tracking, the triple-GEM and low-mass, large-area effort for forward tracking and particle identification with hybrid MPGDs for a RICH detector. The committee is very pleased with the increased coordination among FIT, TU, and UVa on the cylindrical μRWELL effort. The work on the cylindrical μRWELL to act as a fast-tracking layer in a non-TPC EIC detector is very encouraging and is strongly encouraged. The current design should be re-evaluated with detailed simulations leading to an optimized design. The construction of a mock-up mechanical prototype is encouraged. Understanding of the μRWELL prototype results should be a high priority, in particular understanding the efficiency and the gain uniformity.

The beam test efforts to evaluate various MPGD-based readout possibilities for a TPC, tested in a planar detector configuration with "multi-zigzag" printed circuit board, is very helpful and will aid in developing a quantitative metric to evaluate various technologies and designs. Preliminary analysis results were shown and completing the studies is strongly encouraged. The study of IBF blocking structures to be used in an MPGD-based readout structure for a TPC and the development of new gating grids seems promising and should be pursued. We encourage tests in a magnetic field with a laser, for example.

FIT has continued to work on the two low-mass prototype GEM forward tracking module and to characterize its performance. Hit residuals were shown at the last meeting for tracks through the forward low-mass GEM chambers to study how the reduction of material affects the spread of track position due to multiple scattering. No noticeable difference was reported, though a full study of the physics impact was not completed. The committee supports the completion of the characterization of the two low-mass large-area forward triple GEM detector prototypes including beam tests. This effort has been ongoing for a while and swift completion of this task is encouraged.

The development of hybrid MPGDs for a window-less RICH detector for high momentum hadrons, where the radiator gas is also the detector gas, is very intriguing. A very high quantum efficiency was reported for hydrogenated nano-diamond powders at low wavelengths. Studies of the gain versus time showed unexpected behavior. Completing the studies and gaining and understanding of the time dependence of the gain is strongly encouraged. Simulating the performance in a real-life photodetector would be very helpful.

Stony Brook has carried out a detailed study of the IBF in the context of an sPHENIX TPC to derive the hit resolutions through simulations. They also initiated a study of the use of optical materials to tailor the Cherenkov effect in a way that would greatly improve the particle ID reach. COMSOL-based simulation studies have started, and they are able to reproduce various published results. Attempts to invite experts in the field have been unsuccessful.

Recommendation:

It is recommended to carry out a quantitative comparison of the various MPGD technologies, identify the technological roadblocks of the most promising technologies and prioritize the R&D accordingly.

The proposal to develop an outgassing facility at Temple University is well-received, but is deemed to be

not cost-effective. The team provided the committee with a quote from Integrity Testing Laboratory, which indicates that the required information is readily available commercially. Support for the construction of the outgassing facility is hence given low priority.

The difficulties with Chromium GEM foils seems to be the purview of the foil producer. We encourage this R&D but support it being carried out outside of this EIC R&D program.

The study of meta-materials is very intriguing and could hold a lot of promise, but the required timescale for bringing it to a technological readiness level required for a CDR seems long.

At the last meeting it was noted that the consortium was established to increase the coherence, synergies and collaborative efforts and share techniques, experiences, equipment and even interchange personnel to maximize the efficiency of the R&D efforts. Although there is clear progress, the consortium could further improve on better articulating the added value of being a consortium.

eRD14: Integrated Particle Identification for a Future EIC

P. Nadel-Turonski reporting

The eRD14 collaboration is making progress towards the realization of particle identification for the EIC, but progress is made at a slower pace than expected. The committee makes the following observations based on the progress report:

Detectors:

SiPMT is the only detector working at 3 Tesla at present. If the SiPMT radiation damage can be handled by cooling, as CMS studies indicate, one should put start an effort to understand how to cool them and to what temperature and prove that all this works, first in calculation, and then in a test beam. If SiPMTs will fail this test, this detector should be dropped from consideration. Commercial MCPs made by Photonis are an available solution for fields up to 1.5 Tesla. LAPPD detectors do not make sense unless they provide pixel sizes between 3-5 mm and operate at 1.5 Tesla.

dRICH:

The dRICH group has finished MC studies of its performance. They also proposed a concept prototype for the test beam. This prototype will certainly be useful at some point. However, one should realize that it is not a trivial test. It requires a Freon purification scheme, very good Si-tracking detectors, beam PID detectors, complex electronics, understanding of Aerogel quality, mirror development, etc. This will require a fair amount of preparation time and resources. This would be a very valuable test to carry out, but the committee is not convinced that the consortium is ready and has the resources to carry out this project at this time.

mRICH:

The mRICH group hopes to provide hadron PID capability with momentum coverage from 3 GeV/c to 10 GeV/c and e/π separation at lower momenta below 2 GeV/c. The good news is that the plastic Fresnel lens seems to be sufficiently radiation hard. mRICH has performed beam tests indicating clear Cherenkov rings. However, the committee would like to see results in terms of the Cherenkov ring resolution, average number of photoelectrons per ring, and projected PID performance next time as asked before.

DIRC:

The DIRC group has performed useful radiation hardness tests of various material candidates for a lens. It would be nice to see if PbF_2 and Sapphire materials can actually be manufactured to make real lenses. To evaluate lenses, an optical mapping system has been prepared and is ready to be used. The group presented the latest Panda DIRC test beam results with 5mm pixel readout. Tests of a Panda prototype at Fermilab would be useful if instrumented with eight MCPs with 3mm pixels. That may be ready in 2 years from now. It is important to fund one Photonis MCP tube with 3 mm pixels at this point, so that JLAB people can evaluate it. A beam test is a non-trivial effort, for the same reason as beam tests of dRICH or mRICH.

Mini-DIRC:

A mini-DIRC for the very far forward region was proposed. This near-beam ion identification seems like a good idea, but a more detailed proposal is needed with justification for the physics case should be given before proceeding.

MCP tests in magnetic field:
One of the outstanding questions, which was not answered by Panda is why ALD coating affects the gain dependence on the magnetic field. Investigation of this effect is encouraged.

Ion feedback study:
JLAB presented a study of the ion feedback in a Photonis MCP. They found that the ion feedback does not depend on magnetic field, for a constant gain. This agrees with results at SLAC from 2007.

Electronics:
The committee sees good progress in the area of electronics. This electronics development is essential at this point to evaluate various RICH detector concepts in test beams and in test benches. However, one should not forget that there are alternatives to waveform digitizing electronics employing time-over-threshold pulse height correction to timing; examples are the NINO ASIC or the TOPFET2 ASIC, used by TORCH and Panda Endcap DIRC and others.

Recommendation:

The consortium was formed to make the multiple R&D efforts more coherent. Although there is good progress, the progress does not be at a pace where a CDR can be proposed in a few years. TO better understand the various part a more in-depth discussion is asked for before specific recommendations will be given. The committee would like to have a dedicated video meeting with all the subdetector leads in early September to further evaluate the strategic direction of the consortium.

eRD15: Compton Polarimetry

No report

eRD16: Forward Silicon Tracking

E. Sichtermann reporting

We acknowledge the team's adoption of the requested reporting format. Good progress has been made since the last presentation. We note however, lingering concerns of discrepancy between different simulation tools, particularly at low rapidity, where the results should be simple.

We were pleased to see the considerable progress made on a study of the all-Si tracker and its excellent performance on parametrics at a reduced radius, as compared to a TPC. It would be interesting to understand how well it would function in a multi-particle environment with respect to pattern recognition, and how the required number of layers and layer distribution would affect that, and the impact of any additional material.

As discussed in the written proposal, the planned future work on mechanical support, material, and engineering is, to us, an excellent direction going forward, and will add even greater insight into the practical and performance aspects of this tracker.

The Committee acknowledges that this ongoing work on layout simulation is being done with increasing collaboration with RD18 and looks forward to the report later this summer.

Recommendations

The Committee recommends that this proposal be supported in full and agrees that the workplan and studies be completed, as described are correct, going forward.

eRD17: EIC Calorimetry: Beagle

M. Baker reporting

BeAGLE is a generator to describe eA collisions for the EIC. The proponents use real data from E665 to validate the physics model. The code is being used for physics-driven refinement of detector requirements, particularly in the forward region at both BNL and JLab and is essential in establishing EIC detector requirements

The proponents again submitted a report clearly delineating the progress made and the plan for future work. The 'big picture' is that developing an eA generator is a highly complex task because of the varieties of physics processes that are to be studied. BeAGLE is already fairly complete as regards deep inelastic scattering, so the current focus is on diffractive interactions, not only because the physics is interesting – diffraction is the only process which allows us to map the spatial distribution of gluons in nuclei---but also because it impacts detector requirements. There is now a particular focus on incoherent diffraction for two reasons: (i) Incoherent diffraction is an important background for coherent diffraction (incoherent diffraction swamps coherent diffraction unless the incoherent events can be vetoed efficiently); (ii) Incoherent diffraction is of interest in its own right as a probe of saturation.

Improved understanding of the incoherent process and of nuclear excitation in particular have indicated that the necessary vetoing will be harder than at first assumed. Thus, BeAGLE must be upgraded to use process-dependent dipole cross sections and to use the more sophisticated description of diffractive events provided by RAPGAP rather than PYTHIA. BeAGLE must be tuned to describe all relevant data, principally that from E665. Effort to make contact with E665 streamer chamber using heavy noble gas is planned after the ongoing work and will be of interest here.

Notably BeAGLE is able to cope with both eRHIC and JLEIC designs and its use has become more widespread in the community since the group has provided good documentation and user support. Examples were given of independent use of the code, which is most encouraging.

The Committee would like to comment on the use of Monte-Carlos in High-Energy Physics. The PYTHIA Monte-Carlo for hadron-hadron physics was born in 1982 and it has continued to develop in the light of new measurements to the present day. It has dedicated developers who spend substantial amounts of their research time on it (mostly theoreticians including Sjostrand, Lonnblad, Ingelmann and others). Considering the small amount of manpower on BeAGLE it is remarkable that they achieve as much as they do with as few people as they have.

The group has achieved a substantial number of goals projected for mid-2019. They have implemented various technical improvements and bug-fixes and made substantial progress on supporting physics driven studies of forward detector performance and on tuning BeAGLE to the E665 data. They are expecting to be able to complete the majority of the additional work to give the EIC community a sophisticated eA generator by the end of FY2020.

Recommendation:

The Committee looks forward to the completion of this demanding development cycle and a transfer of the responsibility to a laboratory or university to maintain and support the software package.

eRD18: Precision Central Silicon Tracking & Vertexing for the EIC

L. Gonella reporting

At the time of the Jan 2019 review the Committee made a set of recommendations:

- Reconcile the differences in resolution between the various simulation tools and between eRD16 and eRD18
- Further advance and clarify the characterization studies underway for the TJ structures
- Clarify with eRD16 the role and necessity of a timing layer, particularly since you propose to expend EIC R&D resources on electronic design for it. It would be great to see a more definitive and coherent discussion of this in July
- Carry out the proposed design plan, which has been funded, at RAL.
- Pursue with eRD16 a broader tracking workshop

We note that these were largely addressed. As a highlight, the presentation focused on the evaluation and evolution of the TJ test devices. The improved collection volume described is a significant achievement. We also note that the work shown on timing requirements, and options for implementation – calibration and constant fraction discrimination – was interesting and enlightening. We look forward to further exploration and clarification of this aspect.

We further look forward to future proposals to realize the design and production if the first specific EIC DMAPS sensor, beginning in January 2020.

The Committee acknowledges the ongoing work on layout simulation done with increasing collaboration with eRD16 and looks forward to the report later this summer.

Recommendation:

The Committee recommends supporting the proposal at the full requested funding

eRD20: Software Development

Markus Diefenthaler reporting

The committee is very pleased with the outreach activities of the EIC Software Consortium (ESC) to help ease entry of the user community into detailed simulation efforts. Three large initiatives were organized, in particular a meeting on Machine Learning, Monte Carlo Event Generators and a general EIC software meeting. The emphasis has been on developing the workflow environment for the EIC User Group in the areas of tool use, development of the documentation and receiving user input. Several user interfaces were developed that are of general use. More effort in this area is strongly encouraged. A single point of entry has been established for users at the EIC Software website: https://eic.gitlab.io

The relationship with the Software Working group of the EIC User Group is of some concern and carries the risk that the effort may become more fragmented. Strong coordination between the ESC and this working group is encouraged.

The day prior to the start of this meeting there was an EIC Software Meeting on Detector and Physics Simulations organized by the ESC, which provided valuable feedback to the ESC. A set of software development meetings are scheduled which will help advance the software development for the EIC and increase the reliability of the simulations. It is great to see the development of containers and reconstruction tools. The effort on providing common interfaces is strongly supported.

Recommendation:

The committee appreciates the request of the ESC for support for a full-time postdoc to advance the software status. The level of effort that the EIC needs, however, is much larger. The committee urges the user community and the laboratories to engage more in developing a cogent strategy for the software support. With the prospect of a CDR in two years, the time is now to bring this effort to a much higher level.

eRD21: Background Studies

Charles Hyde reporting

The eRD21 studies of beam-induced backgrounds have advanced well with notable achievements in several areas.

A shorter, water-cooled beryllium central chamber has been designed with smoother transitions to the beam pipe to minimize beam wakefield and maximize pumping conductance. Even with the 12 mm radius synchrotron radiation (SR) mask constriction, the Molflow+ vacuum model shows simulated pressure distributions achieving below 10^{-10} Torr in the interaction region (IR). However, any chamber material irradiated by SR in the central region, especially the SR mask, has the potential to become a source of beam-gas backgrounds due to dynamic outgassing. Initial progress has been made towards estimating this effect in SYNRAD, by calculating the photon flux and spectra (the committee was eager to see results of SR focusing on beam tails in July). Since May 2019, an initial GEANT4 model of the electron beam pipe and two layers of silicon vertex tracker (SVT) has been developed. In future the integration of the SR flux simulation and detector simulation will be required to estimate the SR dynamic background and then iteratively optimize the design. The group has started examining neutrons, via e.g. the use of FLUKA. This is important; the group is encouraged to contact persons using the MARS code (FNAL) to address transport of neutrons, including low-energy ones down to 1 MeV and less, and other particles, in particular in the vicinity of accelerator lattices. The Committee takes note that the SR code used is now ported to JLab and in regular use there. The amount of SR power reaching a total absorption counter placed in the electron chicane region, behind a planned pair spectrometer, is impressive, over a kW, and will need to be addressed and shielded in a final design. Detector rates and occupancies resulting from the SR can now be studied and the Committee looks forward to further results.

Section 1.3 of the report indicates a manuscript is being prepared on beam-gas studies in comparison to HERA-II backgrounds, which is a useful validation step, though no results are shown in the report. The committee previously recommended the eRD21 proponents assess upstream beam-gas interactions which can produce particle showers with shallow opening angles that may dominate occupancy levels in the SVT. Such studies are still to be addressed though they are recognized as future work in section 2.1, along with studies of thermal neutrons. The JLEIC baseline optics design has been adapted for higher ion momenta (P_A / Z = 200 GeV). This increase makes upstream beam-gas studies even more relevant, as secondary particles produced in ion-beam-gas interactions will have more energy to reach the SVT. The group is encouraged to make further contact with the various groups pursuing Silicon-based sensors in order to incorporate details of those proposed detectors, notably the thickness of the sensitive layers, in their studies.

A beam-beam analytic model of the total electron-ion hadronic production cross-section has been developed and the inclusive and tagged rates for quasi-real photo-production are calculated. These estimates exclude the large crossing angle. [A previous comment by this committee was to check if backgrounds may arise from parasitic collisions between incoming and outgoing bunches, as occurs at LHC. This remains unchecked in the report; however, it may be reasonably excluded at JLEIC from a quick estimate of the beam-beam overlap, based on bunch dimensions and timing: A collision frequency of 476 MHz implies a bunch spacing of ~2.1 ns. As the outgoing bunch passes the next incoming bunch at 1 ns (0.3 m) downstream of the IR, the very large crossing angle of 50 mrad (x400 larger than at the LHC) implies a transverse separation of ~15 mm between bunches. The separation is much larger than the

normalized emittance in x of 54 μm.]

The proposed luminosity monitor based on backward Optical Transition Radiation (OTR) is a promising solution to measure the total flux of well separated e^+e^- pairs converted from bremsstrahlung. The ellipsoidal OTR radiator that focuses light to a distant PMT would resolve bunch-time structure and should be investigated if the budget allows. Another potential advantage of using OTR is that observation of the non-uniform OTR point spread function (for example from a flat target, via a lens and polarizer to a 2D detector), may simultaneously enable the total current and transverse size of the low Q^2 electrons to be monitored, if required.

Recommendation:
The Committee suggests for now to concentrate on the accelerator background studies already in progress. A future proposal aimed at luminosity monitoring should be considered, but the OTR is given lower priority at this point in time.

eRD22: GEM-based Transition Radiation Detector

Yulia Furletova reporting

A GEM based Transition Radiation Detector (TRD) prototype is being studied as particle id detector for the forward region. Extensive MC studies were performed, which will help to define the detector design better. The committee feels that there is a need to improve material choice for the interface between TPC and radiator. It was suggested to use carbon-loaded Kapton foil made by DuPont as one option.

The gas mixing system is completed, operational and ready. There is no re-circulation at present. There is also no Xe-getter to clean the Xe gas. We are told that they purchase the cleanest possible Xe and that seems to work so far.

Due to technical problems, there is a half-year delay to perform a beam test with hadrons, either at Fermilab or at GLUEX in front of the DIRC. The test in a hadron beam is very important.

We find that the Flash ADC 125MHz has excellent performance. The pre-amplifiers exhibit an undershoot due to the lack of a baseline restorer which causes the loss of clusters.

Recommendation:

It is recommended that eRD22 develop a clear set of specifications for the readout and explore what options are available with the broader community so that a definitive test can be mounted to demonstrate the feasibility of this detector.

eRD23: Streaming Readout

J. Bernauer reporting

An interesting beginning of a cost-benefit analysis of possible readout architectures focusing on minimizing custom trigger hardware and relying, as much as possible, on commercial computing for data selection has been presented. Without any particular set of requirements from a particular set of detector subsystems it is not clear that one can yet make any firm conclusions on where an optimum design might lie. It should be noted that all the variants mentioned assumed on-detector zero suppression and so some level of local “triggering”. This topic will be of increasing interest as detector ideas converge and as real detector design communities emerge.

Recommendation:
Modest funding is suggested to continue to encourage discussions of options and development of the means of completing a detailed cost benefit analysis once more is known about the EIC detector(s).

New Proposal: Design of an Integrated Silicon Sensor

J. Repond reporting

This proposal intends to further progress on the very fast timing calorimeter proposed in the TOPSiDE detector concept. The proponents have simulated good Pi-K separation up to 7 GeV using 10 ps timing resolution in a pixelated readout. Unfortunately, that separation appears to disappear if the achieved resolution were only 20 ps. The proposal does not address any of the system level issues that would arise in an actual detector. At a 50 ps resolution, this TOF concept does not work.

The first few LGAD sensors were tested in a 120 GeV proton beam at Fermilab and timing difference between two identical sensors gave a resolution of ~42 ps per sensor at 25 ^{0}C. The final application would require cooling sensors to improve the S/N ratio.

The proponents claim a power consumption of 500 mW/cm^2 for the sensor, or 90 W/layer or 1.8 kW/calorimeter. There were concerns if this is correct.

Proponents presented a schematic design of one LGAD sensor, and a schematic of the electronic readout for every pixel. The committee thought that the project is more expensive and difficult and would require more resources than one postdoc and more than $30k. The allocated resources were thought to be very insufficient to successfully realize this project.

Whether the readout was actually integrated with the LGAD sensor as proposed or implemented as a separate readout device, the 10 ps resolution target is immensely challenging. In this same meeting there was a presentation of an advanced but incomplete design of a MAPs device with slightly smaller pixels (350 vs. 1000 μm square) that was expected to be able to reach 3 ns timing resolution within an acceptable power budget. Without any clear indication that an integrated LGAD / analog / digital device or, indeed, a separated LGAD / readout device is possible with present day technology and given the extreme limitations on the budget, funding is not recommended. We encourage people to improve the proposal.

Recommendation:

The proponents are encouraged to flesh out the proposal in much greater detail and resubmit.

New Proposal: Roman Pots

A. Tricoli reporting

This proposal is supported by a strong physics case and the first steps planned are to flesh out that case and establish the requirements for the detectors that would occupy the far forward Roman Pots in terms of spatial and temporal resolution. However, actually implementing such detectors may prove challenging in the extreme. The LGAD sensors are promising devices that may meet the expected requirements in terms of timing and loss of efficiency at the edges. However there does not yet seem to be a clear plan for how such devices would be read out if the required pixel size is on the order 50 to 100 μm square. A 100 μm square pixel gives 10,000 pixels per cm^2. If a preamplifier with sub ns rise time, a shaping amplifier, a constant fraction discriminator and a TDC with ~10 ps resolution could be integrated in a readout chip in a 100 um x 100 μm area for ~1mW per circuit that would still give $10W/cm^2$ which is comparable to the power density of a modern processor and would require a significant cooling infrastructure with associated mass and high Z materials. An early plausibility demonstration that the cooling problem can be solved would be valuable. Note that there was a report in this meeting of a partially complete sophisticated MAPS based design that would achieve ~ 3ns resolution for 350 um pixels at an acceptable power budget. So what is proposed here goes significantly beyond this. We note also a comment to the effect that position measurement and timing could, perhaps, be enacted in separate adjacent layers. Of course, this would require a more detailed understanding of the geometry, accessibility, and infrastructure around the proposed Roman Pot installation.

Recommendation:

We recommend that this proposal be funded at the requested level and look forward to hearing much more quantitative specifications, requirements, and technical plausibility at the next meeting. We also would like to see more clarity on the physical layout of the proposed system. What limitations are set by geometry, access, services and so forth. This proposal will be categorized as eRD24.

New Proposal: Generic Tracking Tool

J. Repond reporting

The group proposes to develop a tracking tool to support the performance of an ambitious detector modelled upon the TOPSIDE concept. This is a particularly-fine-grained "imaging" calorimeter equipped throughout its volume with some tens of millions of sensors capable of providing energy-deposit as well as timing information with 10 ps precision. The predicted performance of this detector evidently depends upon development of a fast sensor providing 10ps timing, which was the subject of another proposal.

The tracking tool would focus its early development on, first a Hough transform suitable for tracking in a magnetic field, followed by a second major step addressing pattern recognition/track finding using machine-learning techniques. Later steps would cover particle flow algorithms using the pattern-recognition as input, with a following particle-identification step. Little information was provided on the essential machine-learning step.

Recommendation:

The committee at this point is not confident that this effort would be a good investment until the technical performance needed for the sensing elements can be demonstrated in bulk. Thus, the Committee does not recommend pursuing this effort at this time.

Funding Summary for FY20

EIC Detector R&D FY2020	PI	Progress Report and/or Proposal	FY20 Sub-proposals	FY20 Requested Funding	Priority
eRD1	Huan Huang (UCLA), Craig Woody (BNL)	EIC Calorimeter Development	Shashlik Calorimeter	$75,000	Medium
			HCAL and timing	$51,200	Low
			PWO	$40,000	Low
			Glass Ceramics	$80,000	High
eRD3	Professor Bernd Surrow and Dr. Matt Posik (Temple University) / Dr. Franck Sabatie	Design and assembly of fast and lightweight forward tracking prototype systems for an EIC		$0	N/A
eRD6	Kondo Gnanvo (UVA)	Tracking and PID detector R&D towards an EIC detector	MPGD-RICH	$44,000	High
			μRWell	$74,700	High
			TPC Readouts	$75,000	Low
			Meta-Materials	$0	Low
			Outgassing	$56,200	Low
			Forward Tracker	$22,000	Medium
eRD14	P.Nadel Turonski (Stony Brook), Yordanka Ilieva (S. Carolina)	An integrated program for particle identification (PID) for a future Electron-Ion Collider (EIC) detector	dRICH	$52,000	Medium
			mRICH	$78,300	Medium
			DIRC	$134,000	High
			high-B	$39,300	Low
			LAPPD	$120,000	Medium
			Electronics	$92,000	Medium
eRD15	Alexandre Camsonne(JLAB)	R&D for a Compton Electron Detector		$0	
eRD16	Ernst Sichtermann (LBL)	Forward/Backward Tracking at EIC using MAPS Detectors	Simulations	$41,596	High
eRD17	Mark Baker	BeAGLE: A Tool to Refine Detector Requirements for eA Collisions in the Nuclear Shadowing/Saturation		$88,020	High
eRD18	Peter Jones (Birmingham, UK)	Precision Central Silicon Tracking & Vertexing for the EIC	Sensor Development	$18,000	High
eRD20	Markus Diefenthaler (JLAB), Alexander Kiselev (BNL)	Developing Simulation and Analysis Tools for the EIC	Postdoc	$120,000	Low
			Travel	$20,000	High
eRD21	Latifa Elouadrhiri (JLAB)	EIC Background Studies and the Impact on the IR and Detector design	0.5 FTE Postdoc	$51,000	High
			0.5 FTE Postdoc	$51,000	High
			Graduate Student	$25,000	Low
			OTR	$20,000	Low
			Travel	$8,000	Medium
eRD22	Yulia Furletova (JLAB)	GEM based Transition Radiation Tracker R&D for EIC	Gas System Temple	$9,510	Low
			Xe gas system, JLAB	$27,010	High
			Prototyping, UVA	$18,075	High
eRD23	J. Bernauer	Streaming Readout for EIC Detectors		$20,000	Medium
New Proposal	J. Repond	Design of an integrated Si sensor	1 Postdoc + 30k M&S	$155,000	Low
New Proposal	A. Tricoli	Roman Pots	Labor (20) + MS (10) + Travel (5)	$35,000	High
New Proposal	J. Repond	Generic Tracking Tool	0.5 Postdoc + travel	$67,500	Low

Table 1: Summary of the funding recommendations.